BENIGN PAROXYSISMAL POSITIONAL VERTIGO REHABILITATION BY VIRTUAL REALITY AND MULTISENSORIAL STIMULATION

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Abstract.

Balance is due to proprioception, vision, vestibule and visual dependence, but an imbalance in one of these components will create the sensation of benign paroxysmal positional vertigo(BPPV). The purpose of the study is to demonstrate the usefulness of virtual reality on BPPV. Method and material: we tested 15 subjects, with an average age of 58 years, 7 men and 8 women, diagnosed with BPPV. Before(T1) and after evaluation(T2) was realized with: Stepping Test, Babinski Weil and a complex evaluation using MotinVR-Platform. The rehabilitation during 6 months, 2 sessions/week, each session 10 minutes muscle strength, proprioceptive stimulation, balance exercises and 20 minutes of multisensory stimulation. The result:Stepping Test, 29% of the subjects show a deviation to the left, 71% to the right. Following Babinski Weil, 4 subjects had a fall to the left, 10 subjects had a fall to the left and only one subject had no fall. On MotionVR-Platform, the results on average are: somesthetic input: 92.1%(T1) and 97.5%, (T2), visual input:57.7%(T1) and 71.3%,(T2), vestibular input:59.9%(T1) and 69.2%(T2) and visual dependence: 89.3%(T1) and 98.4%(T2). The postural stability with eyes open on stable plane: 82.2%(T1) and 86,5%(T2), eyes open on unstable plane 52.7%(T1) and 61.7%(T2); eyes closed on stable plane 82.5%(T1) and 89.5%(T2), eyes closed on unstable plane:52.1%(T1) and 63.0%(T2); controlled vision on a stable plane:82.2%(T1) and 89.1%(T2); controlled vision on an unstable plane:41.5% and 58.9%(T2).Conclusion: each subject requires a complex multisensory rehabilitation, based on vestibular, proprioceptive, visual stimulation, these three can be combined at the same time on the MotionVR-Platform.

Key words: balance rehabilitation, multisensory stimulation, virtual reality.

Introduction:

The biological plausibility of VR-based rehabilitation lies in the ability to induce cortical reorganization (e.g., in chronic PS) (Levin et al., 2005) and to enhance experience-dependent neural plasticity by incorporating such learning principles motor such as real-time feedback; Attentional focus and implicit learning (Levin et al., 2015; Kleim & Jones, 2008; Papegaaij et al., 2017).

There are three theories in the literature about how people adapt to vestibular disability; these include adaptation, substitution, and habituation of the vestibulo-ocular reflex (Szturm et al., 1994). Vestibulo-ocular adaptation is most commonly used in the rehabilitation of people with vestibular disorders.

The type of vestibulo-ocular reflex adaptation exercise produces a rebalancing of the vestibulo-ocular reflex function after vestibular disability (Shelhamer et al. ,1994).

Cass et al. (1996) define vestibular physiotherapy as an exercise program designed either to adapt the vestibulo-ocular reflex, is to accustom the person to movement, or to teach sensory substitution, as well as to improve a person's balance / postural control. The above-mentioned research reported that 60% of patients who participated in a vestibular exercise program after surgery showed an objective improvement in balance function, 25% of patients improving normal balance values in the posturography sensory organization test. computer dynamics. Vestibular exercises improve vestibulo-spinal compensation in patients with acute peripheral vestibular disorders.

Bray (2004) in the article titled “We are most aware of our place in the world when about to fall” provides evidence of vestibular rehabilitation interventions, which work best when individuals obtain information about guidance through actions and reactions. Providing balance therapies (actions) that require the use of vestibular information are essential (Peterka, 2002).

Virtual reality also facilitates goal progression and task variation and specificity, subsequently allowing the efficiency and application of motor learning strategies during rehabilitation treatments (Levac et al., 2011).

Virtual reality refers to the realization of realistic environments, although they are artificial, that are simulated by computer and that are experienced by users through human-machine interfaces involving several sensory channels. In this respect, comparable technical solutions are applicable in various fields, such as cyberspace, virtual environments, remote operation, telerobotics, augmented reality and synthetic environments. This applies to various conditions, such as: design, engineering, production and marketing; medicine and healthcare; online monitoring of children and the elderly at home and accident prevention; hazardous operations in extreme or hostile environments; and medical education and surgical planning/training, etc.

The combination of virtual reality and daily life with direct or indirect connections of the actual environmental rehabilitation process, the elements of which are formed proportionally with the help of software, generates useful images for the rehabilitation needs of the subjects. Augmented reality is widely used in surgery, virtual endoscopy, radiation therapy, neuropsychological assessment and medical rehabilitation (Gorini and Riva, 2008a; Gorini and Riva, 2008b).

On the other hand, Miniconi (2016) in the article “Postural response of the vestibulospinal reflex during active dynamic movement in the plane of the six semicircular canals” proposes a new test for exploring the function of the six semicircular canals, during a clinical otoneurologic examination.

Very simple to perform, this test helps guide the diagnosis in patients who complain of balance disorders (dizziness, instability, falls). He studies the postural response of the vestibulo-spinal reflex during dynamic stimulation in the plane of each of the six semicircular canals, especially in the anterior right - left posterior and left anterior - right posterior for vertical semicircular canals. The patient is positioned as in the Romberg test, with his legs close together and his eyes closed, he is asked to make a very fast movement of his head to the right in a horizontal plane, and after 4 or 5 seconds to make a movement to the left (lateral semicircular canal). The result of the test is that the patient will fall in rear projection on the affected side.

Material and Method:

Subjects

We tested 15 subjects, with an average age of 58 years, 7 men and 8 women, diagnosed with BPPV. The rehabilitation during 6 months, 2 sessions/week, each session 10 minutes muscle strength, proprioceptive stimulation, balance exercises and 20 minutes of multisensory stimulation.

Functional and specific evaluation

Before and after evaluation was realized with: Stepping Test, Babinski Weil and a complex evaluation using MotinVR-Platform.

Stepping Test

To enrich the assessment of posture, T. Fukuda was inspired by two methods of assessment of the vestibulo-spinal pathway. In 1959, he developed the "step test", realizing that the labyrinthine reflex extended to the lower limbs.

The subject must be blindfolded and then take 50 or 100 steps in place at a rate of 110 steps per minute. The test is conducted in an extremely quiet room with no side lighting. At the end of the test, the rotation angle of the body around the vertical axis, the movement (direction) and distance are measured.

Babinski Weil

The Babinski-Weil test requires patients to take three steps forward with their eyes closed and then three steps back, repeated three times. in the case of BPPV, the subject will turn to the pathological side, thus determining which side is affected.

Evaluation using MotionVR-Platform

Sensory Organization Test software is a captivating 3D simulation based on virtual reality technology: that is, that allows a person to be immersed / included in a digitally created artificial world. SOT software uses dynamic force plate technology to isolate and quantify the contribution of the sensory system to equilibrium. The results are generated in the individual balance score, which is composed as follows: results of sensory analysis, strategy selection according to sensory condition, center of gravity at the beginning of each test, and wavelets and polar waves.

The balance consists of 3 components (figure 1.), namely submission

- proprioception,
- vestibule,
- vision
- visual dependence.

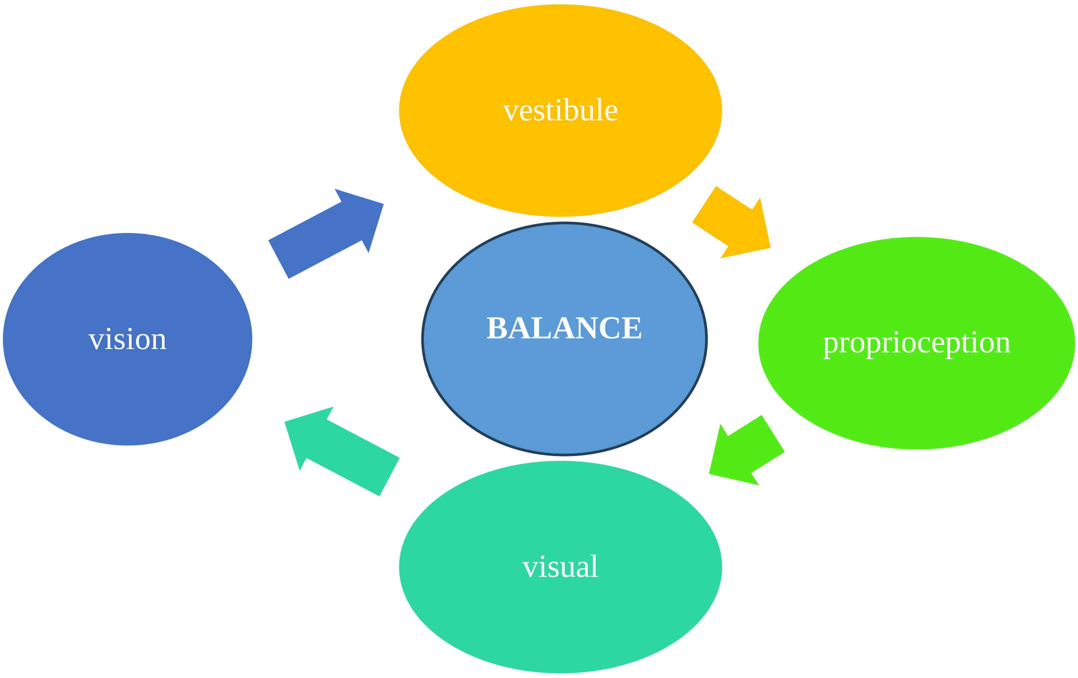

Figure1. *Balance components*

In unilateral vestibular hypofunction it means that there is a conflict between these 4 components (figure 2).

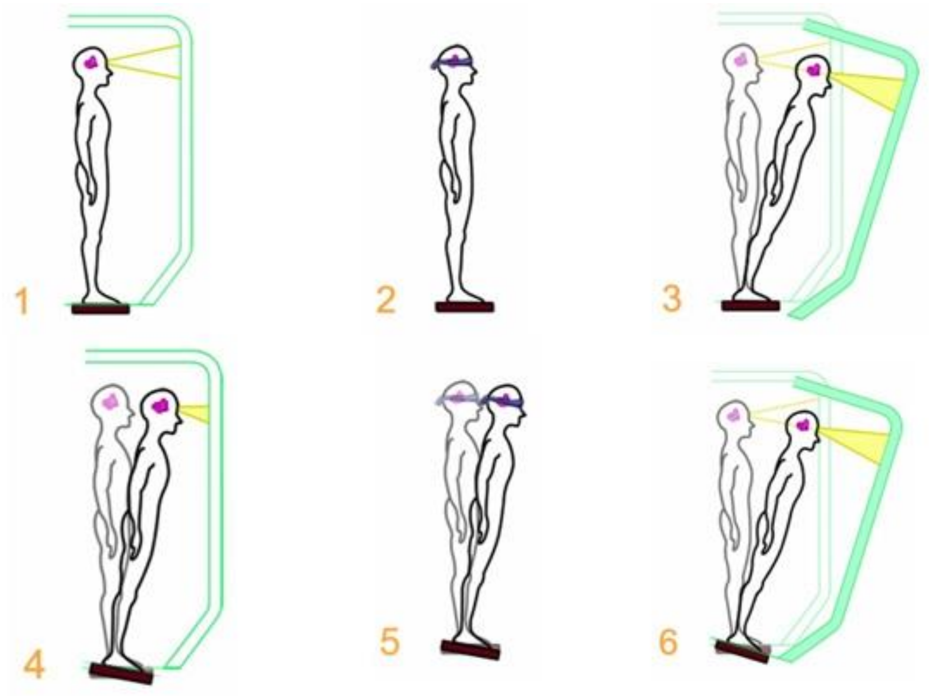

Figure 2. *The 3 sensoriale affrontions – proprioception/somatosensoriel, vestibule, vision.*

Sometimes these 3 components cannot be recovered in their entirety, consequently a lack of balance will be compensated with the help of the Motion VR Platform.

This compensation translates into a rebalancing of the 4 components, and the reduction of vestibulo-spinal and vestibulo-ocular conflicts. Those one has 2 functions really important like:

- the vestibulo-spinal reflex is stabilizing the balance body;
- the vestibular-ocular is stabilizing the image.

Stimulation of vestibulo-spinal conflicts is achieved by strengthening proprioception and by using correctly the ankle strategies.

The rehabilitation

The program of rehabilitation was realized on one period of 7 months (May-December 2022), 2 sessions of rehabilitation every week, with a session of 30 minutes of rehabilitation, each of them being compose as: 10 minutes muscle strength, proprioceptive stimulation, balance exercises and 20 minutes of multisensory stimulation.

To increase the muscles strength, we are starting always with the neck muscles because most of the patients has a frizzing position or neck-blocked.

Normally we are starting with small amplitudes and we are finishing with big amplitudes, fist without resistance and after that with resistance.

Exercises were also performed for the flexibility of the trunk, first exercises for tilting, rotating the trunk and performing activity daily living gestures and posture (such as: recovering an object above the head, bending the torso at 90 degrees as if we wanted to see the flame of the stove, or the search for a canned food in a deep drawer). At the end of strength exercises, we proposed 1-2 minutes of stretching.

In order to obtain the best results, it is extremely important to start recovery as early as possible, this being possible even in the first days of the onset of symptoms.

It was also very important to involve each patient, because the subject has to do regular exercises alone at home and after 7 months the results were positive.

To realize a proprioceptive stimulation with eyes open, closed, stimulation of static balance, walking on a straight line, 3 steps with open eyes for a memorization of the movement scheme, then 3 steps with closed eyes, at the beginning of rehabilitation we can notice a deviation of walking on the affected side, and after a few sessions we notice that the patient deviates at least. In order to increase the difficulty, we ask the patient to do 5 steps, then 7 steps, etc.

Also, to increase the complexity, you can perform exercises on a sponge pillow, walking on the spot on a fixed point, walking on the spot with your eyes closed, favoring the work of one leg balance.

The 20 minutes of multisensory stimulation on Motion VR from May to December 2022, are extremely productive, because after achieving the initial assessment we can use the final parameters, in which the patient is already in difficulty and we can perform an adapted recovery process every day. Each subject benefiting from 2 sessions per week, for 30 minutes.

The rehabilitation protocol included a multisensory stimulation, customized to each patient. This stimulation could be achieved on a stable ground, but creating a vestibulo-ocular rehabilitation, by projecting images, continuing with dynamic images (in a darker environment, without other visual landmarks) and adding a degree of complexity, namely we ask the patient to close his eyes, thus stimulating both the vestibular system and proprioception.

Stimulation of the vestibular-ocular conflict is achieved by creating a visual dependence: FeedBack-type exercises or decreasing visual dependence and increasing spatial orientation by performing closed-eye exercises on a free and unstable plane.

It is also possible to rehabilitate patients due to various passive vestibular rehabilitation programs (Impulsive, Otolithic, Fall Prediction) or active Feedback rehabilitation programs (crowd simulation, highway immersion, etc.) and thus oscillation or motion.

Motion Program is a computer program for controlling the dynamic Motion VR platform. It allows the configuration of the mobility of the Motion VR platform on axes and amplitudes, as well as the speed, responsiveness of the platform to create precise situations of imbalance for rehabilitation purposes.

The dynamic force platform performs tilt or pulsation movements, depending on the chosen parameters.

The patient will need to keep a ball in the center of a circular plate by modulating his planting supports. Its planting supports will move the board in the direction of the support.

The movements programmed by Motion VR will aim to unbalance the subject, he will have to reposition his center of gravity with each change of direction, all this being found in the feedback image projected either on a computer screen or in a virtual reality headset, the center of gravity of the subject being transposed in the image of a sphere located in the center of a disk that represents the surface of the platform.

For the two modes of movement of the platform (tilt or pulse) four types of motion are possible.

Movements in all directions: up, down, forward, right-forward, right-back, backward, left-back, left-forward.

Tilt: 8-way movements: forward, forward-right, right, back-right, backward, back-left, left, forward-left.

Axes: movements in the 4 directions: forward, backward, right, left

Manual movements: will allow the manual selection of the directions of inclination of the platform, selected by the physiotherapist that will appear in blue, thus having in real time a control over the movements that were requested of the subject to execute them.

Results:

The initial assessment was performed on a sample of 15 patients diagnosed with BVVP, starting from a functional assessment using scales such as Stepping Test and Babinski Weil, as well as a complex multisensory assessment consisting of using Motion VR Platform.

Functional evaluation

The functional evaluation includes 2 scales:

- Stepping Test
- Babinski Weil

A complex multisensory assessment consisting of using Motion VR Platform.

Stepping Test

The Stepping Test, 29% of the subjects show a deviation to the left, 71% to the right. Following Babinski Weil, 4 subjects had a fall to the left, 10 subjects had a fall to the left and only one subject had no fall.

Using Stepping Test we realized that 29% of the subjects show a deviation to the left, 71% of the subjects show a deviation to the right.

Babinski Weil

Following Babinski Weil, 4 subjects had a fall to the left, 10 subjects had a fall to the left and only one subject had no fall.

Motion VR Platform

On Motion VR Platform, the results(figure 3) on average are:

1. ***somesthetic*** *input:*
a. *92.1% before rehabilitation;*
b. *97.5%, after rehabilitation.*
2. ***visual*** *input:*
a. *57.7% before rehabilitation;*
b. *71.3% after rehabilitation.*
3. ***vestibular*** *input:*
a. *59.9% before rehabilitation;*
b. *69.2% after rehabilitation.*
4. **visual dependence***:*
a. *89.3% before rehabilitation;*
b. *98.4% after rehabilitation.*

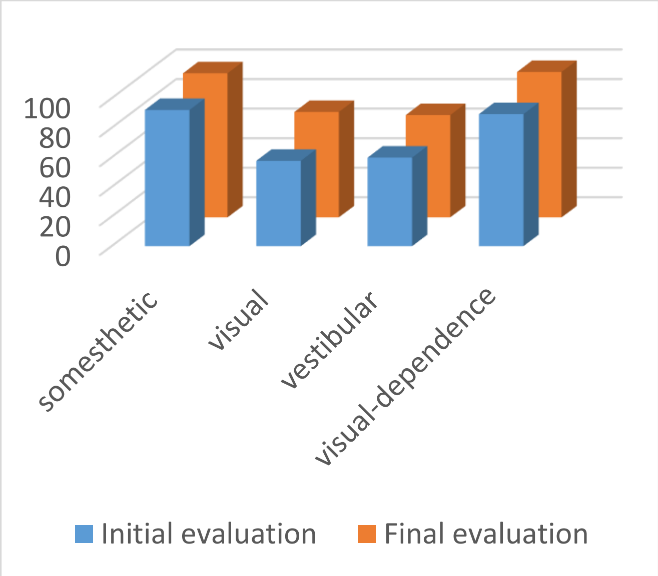

Figure 3: *Sensory Organization Test entrance evaluation*

The postural stability with eyes open on stable plane(figure 4):

1. eyes open on stable plane:

-82.2% before rehabilitation;

-86,5% after rehabilitation;

1. eyes closed on stable plane

-82.5% before rehabilitation;

-after rehabilitation 89.5%;

2. controlled vision on a stable plane:

-82.2% before rehabilitation;

-after rehabilitation 89.1%.

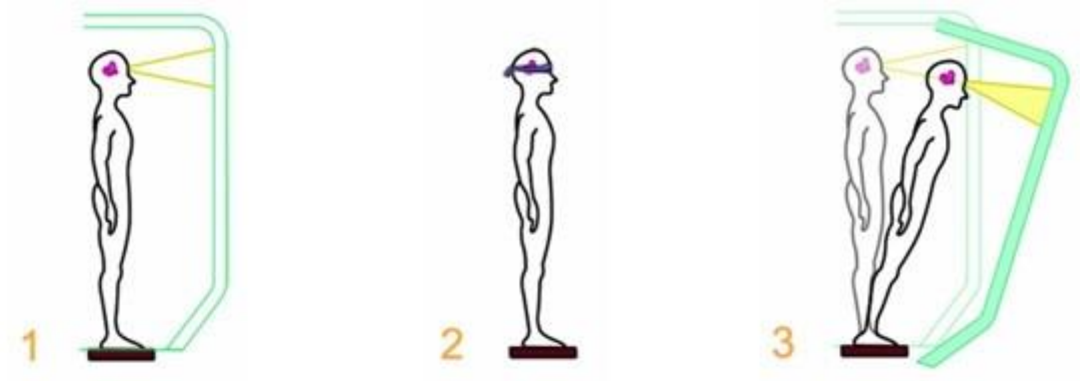

Figure 4. *The postural stability with eyes open on stable plane*

The postural stability with eyes open on an instable plane(Figure 5):

3. eyes open on unstable plane

-52.7% before rehabilitation;

-61.7% after rehabilitation;

4. eyes closed on unstable plane:

-52.1% before rehabilitation;

-63.0% after rehabilitation;

5. controlled vision on an unstable plane:

-41.5% before rehabilitation;

-58.9% after rehabilitation.

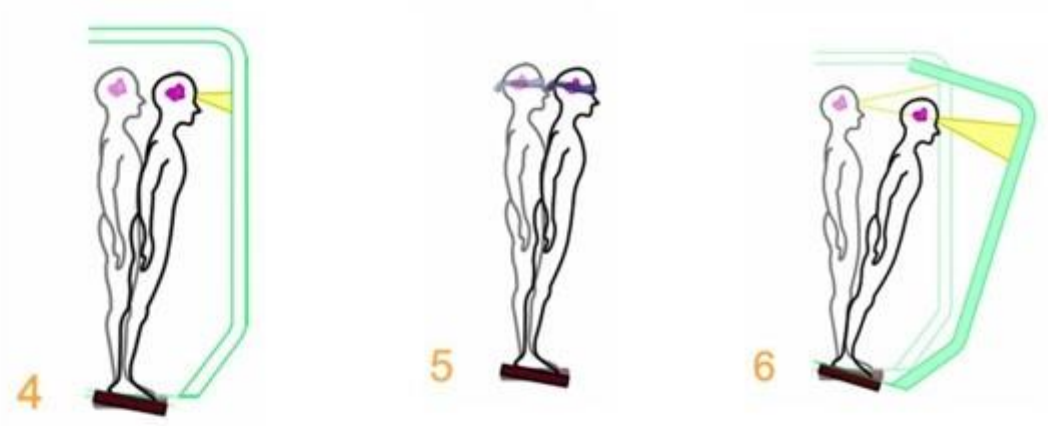

Figure 6. *The postural stability with eyes open on an instable plane*

Discussion

Virtual reality is a new technology defined as „using interactive simulations created with hardware and computer software to provide users with opportunities to interfere in virtual environments, which seem to be real, feel similar to real-world events" (Weiss et al., 2006). In a virtual reality system, the real-world complexity is simulated in a controlled environment.

Moreover, virtual reality can provide a rehabilitation environment, allowing users to repeat the same exercises, while they also have, assessments and sufficient motivation to perform a large number of exercises, all of which are recognized as important components in rehabilitation. Compared to traditional methods, some advantages of virtual reality for rehabilitation include performance feedback, individual configuration, ease of adjustment and the possibility of measuring and quantifying.

Virtual reality also offers an interactive session to facilitate exercise at home in rehabilitation. Moreover, the involvement or pleasure of therapy, reduced pain perception and improved movement can be highlighted in this regard.

Stabilization exercises at a fixed point are based on inducing long-term changes in the neural response of the vestibular system to an error signal specific to the movement of the visual image on the surface of the retina. The sliding of the visual image on large parts of the retina is the stimulus that stimulates the optokinetic movements of the eyes, as well as the stimulus that produces the adaptation (improvement) of the optokinetic system.

The goals of these exercises are to reduce visual blurring during head movement, improve postural stability and reduce symptoms.

The exercises consist of repeated movements of the head while fixing a small stationary target or a target moving in the opposite direction to the movements of the head performed with progressively greater challenges.

Daily exercises should be designed to reduce symptoms by systematically causing these symptoms as noted by Cawthorne (1946), Cooksey (1946), Norre (1980), Telian et al. (1990), Shepard (1993) which includes:

a. stabilization of the gaze (for example, in which the individual has maintained a fixed position of the gaze while turning his head from side to side) in sitting and standing positions),

b. Standing balance (for example, standing with legs apart and feet together on foam with eyes open and closed),

c. walking with the challenge of balance (for example, walking with your head turned, walking in tandem and avoiding obstacles) in some cases, maneuvers to reposition otoliths.

One of the objectives of vestibular rehabilitation is to desensitize patients through progressive exposure, structured to movements and situations that cause symptoms. When the ability to select the appropriate sensory input for postural stability is interrupted, the exercises focus on requiring the individual to maintain balance in situations where the availability and accuracy of one or more sensory inputs are varied.

Referring to the literature we observed that the studies of Hillier and McDonell (2015) and Hansson (2007). also compared the effectiveness of different parameters of vestibular rehabilitation programs. According to the authors, there is insufficient evidence.

The authors could not identify the specific exercise parameters that stood out from the rest due to their high heterogeneity in the various vestibular rehabilitation programs of the studies. Hiller and McDonell (2011) included twelve randomized clinical trials as an integral part of their meta-analysis. The parameters of different interventions for different experimental groups of randomized clinical trials, such as dosage (frequency, intensity, duration), type of exercises and format (in the clinic or self-administered at home) were very varied. In turn, Hansson et al. faced exactly the same problem and also could not draw a conclusion on it.

Various studies have investigated the effectiveness of virtual reality in rehabilitation or the design and development of systems in virtual reality to facilitate rehabilitation exercises.

Virtual reality has also recently been used to stimulate people's recovery from vestibular deficit (Whitney et al., 2006). Visual stimuli seem to help adapt the VOR and improve the functional capabilities of the subject.

The use of vibro-tactile feedback has recently been used to improve postural control while walking in people with vestibular disorders (Dozza et al., 2007).

Trunk stimuli from vibro-tactors appear to improve postural control during position and gait in people with vestibular disorders (Dozza M. et al., 2007).

It should be noted that a review highlighting the effectiveness of Virtual Reality in exercise will be valuable in informing the design and development of future studies. Moreover, physiotherapists can understand virtual reality applications to be used in exercise therapy for various disorders. Therefore, the main objective of this review was to study the effectiveness of the physical exercise based on Virtual Reality in Rehabilitation.

VR rehabilitation is based on the theory that central processing of postural stability and analysis of the meaning of space travel are based on multisensory inputs related to specific requirements of the (Shumway-Cook et al., 2000).

VR rehabilitation can provide standardized or individualized interventions to restore patients' motor functions under multidimensional sensory input.

Conclusions

We note that following this initial assessment, subjects suffering from BVVP have a deviation of gait either forward, backward, right or left, or these deviations can be combined: right projection, left projection, right pre-projection, left pre-projection. -projection. We can also see that after using the evaluation scales, patients have difficulty performing daily activities due to a balance deficit either stationary or dynamic, as well as anxiety and fear of falling. Most of the time, due to this fear, patients tend to make fall protection systems, adopting totally inappropriate gestures and postures, so a well-detailed assessment will reveal all the patient's shortcomings, after which he will create similar or even identical situations. in order to achieve a true re-education. But the realization of this program can sometimes be difficult, delicate and therefore a compensation of the unilateral vestibular hypofunction must be worked.

All this leads us to the conclusion that it is necessary to carry out a special and specific rehabilitation program for each patient through a complex multisensory, vestibular, proprioceptive, visual rehabilitation using the mask of virtual reality creating a real image, these 4 being able to be combined at the same time on Motion VR Platform.

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